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Galena with B high density heavy concrete for shielding nuclear reactors

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Abstract
Shielding of Biological type belonging to nuclear reactor is regarded as an important interest and lowering the complexity and expense of these installations is important issue. In this article, galena minerals and Boron were applied to produce a heavy concrete of high density type. Galena mineral that is present in many regions of Iran were used in the concrete mix design. Boron is considered as a main chemical element for neutron absorption processes. Neutron capture and cross section are two factors that neutron shielding characteristics can explain them. By using a source of 14.1MeV neutrons have done neutron cross section measurements of sample. By using Geant 4 Monte Carlo code, neutron capture and cross section of each sample could be calculated through it. Therefore, high boron concentration can raise cross section value of concrete and develop properties belonging to the neutron shielding.

Keywords: Galena, Boron, neutron cross section, Geant 4 Monte Carlo, heavy concrete, shielding

Introduction

Concrete is a multi-user material and it is usually conventional as energy particles material to protect the users as a result of its cheaper, easier mold into compound form, good structural and appropriate as neutron shielding materials compared to other shielding materials. Y. Abdoullah *et al*. [1] identified that most of the times, aggregate, sand, water and cement comprise concretes. The radiation shielding type belong to nuclear reactor is a costly and intricate procedure. Pavlenko VI *et al*. [2] have recognized that a nuclear reactor usually requires two kinds of shields; one of them to guard the walls of the reactor from radiation harm and at the same time to reflect neutrons back into core; and another, which is called biological shield to protect people and the environment [2]. The biological shield lowers the rank of Gamma radiation and neutrons to current dose limits. The biological shield is comprised of hundreds of centimeters with high density concrete. S.M.J Mortazavi *et al*. [3] found that in the nuclear reactors, neutron is the largest difficult to shield and hydrogen is considered as the largest element that could be efficient in decelerating (thermalizing) neutrons in the whole energy spectrum. The hydrogen that is very large in concrete normally represent the format of water in that it hydrates during cement curing and is added to set free water streaming in the porousness of concrete. T. Korkut *et al*. [14] explored that Boron is an effective chemical element for neutron absorption procedure. It has important implications in shielding technology for the non-deficit shielding characteristics. Baştürk M *et al*. [5] have found that it is an effective absorber that is used in neutron shielding materials. There are various research on radiation shielding by boron combinations [6-10]. Concrete is a frugal and efficient material to be used in shielding reactors. Concrete of high density type has more linear gamma and neutron attenuation properties in comparison to the regular concrete. Sun H *et al*. [11] examined that concrete comprised of Portland cement, sand, aggregate and water is the one with the largest conventional materials applied in the construction of commercial buildings. Now regular concrete (density about 2350kg/m3) is mostly used for superficial and orthovoltage radiotherapy rooms [12]. Galena (PbS) is the major lead minerals [13]. Galena has too cerusssite ($PbCO_3$), plattenerite (PbO_2) and anglesite ($PbSO_4$). This material is a very dense and has density of 7400-7600 kg/m3, so it is closely as dense as iron. The chemical composition and physical properties of Galena are represented in table 1.

In any nuclear reactor, in order to implement radiation shielding, a certain mixture of Portland cement and sand was used, meanwhile boron was considered to be doped with Portland cement in order to create concrete as thermal neutron absorber and lower radioactivity through thermal neutron (Atsuhiko *et al*., 2004).

Table 1: Physical properties of the Galena mineral used in this study

Mineral Properties	Galena
Chemical composition	Lead Sulfide(PbS)
Molecular weight	239.26g
Lead content	86.59% Pb 13.40% S
B2O3 content	---
stiffness	2.5
Density (g/cm3)	7.0-7.5
Color	Gray

The main purposes of this article are to reach to neutron cross section and neutron capture through Geant4 Monte Carlo code for samples. Cross section according B percentage for Galena is shown in table2.

Material and Methods

The starting materials included gravel, sand, cement, water, micro siliceous and Boron. Minerals of Galena were applied for production of a high density concrete. Concrete must include a large amount of water in order to be used as a shield in nuclear type reactors. Higher water content cause concrete efficiency to be more than regular concrete. In this study two types of concrete mixes were produced. First, gravel, sand, cement, water and micro siliceous do comprise regular concrete mixes. Second, GaB concrete Galena and B were applied to completely replace sand concrete mixture. Concentration of Galena and Boron (B) in concretes represented in table 3. Cross section according neutron capture is shown in fig.1 and cross section according Density is shown in fig.2.
Radiation test was carried out by encountering to neutron source 241Am-Be (number of events processed 100000).

Monte Carlo Simulation

The Geant4 program is useful materials. The units are traditionally the barn where 1 barn is equivalent
Simulation devices for several some to 10cm. applications like high energy physics. The interaction and propagation in matter of neutrons in shielding plan could be simulated by Geant4. Cross section and neutron capture were obtained through Geant4 Monte Carlo code. In first place, atomic stoichiometric and densities of samples have been entered. In second place, simulation has been started for 100000 primary neutron particles.

Results and Discussion

The cross section and neutron capture are considered as the influential factors to determine neutron shielding characteristics of sample. No simple scaling law exists for neutron linear attenuation coefficient S. But the cross section is described and denoted by S for neutron. The linear attenuation coefficient has several units, such as inverse length, generally pointed out by cm-1. The microscopic extent about neutron interaction with matter named the cross section (s). The effective cross sectional region to neutrons represented by any of nucleus of attenuating A neutron detector measure the neutron cross section yielded cross section and neutron capture. The measured values of cross section by using Geant4 are shown that are considered as a function of the percentage of the Boron in table2 and Cross section according neutron capture is shown in fig.1.
As can be observed from table2, the more cross section increases, the percentage of Boron in the samples increases too. It is seen successfully that the neutron cross section are strongly dependent on the Boron intensity in the matter and as can be seen from fig.1 that 55% B + 45% Galena with density of 4.70 have high cross section value and so it have high neutron shielding properties in compare to other samples.
Also the measured values of cross section and neutron capture by using Geant4 are shown as a function of density is shown in table2 through cross section and cross section according to density is shown in fig.2. As it was proposed above, Boron percentage is effective on neutron shielding capability of matter. Consequently, as can be seen from fig.1, %45 Galena + %55 Boron is more effective shielding material because it has high cross section value.
As it is observed in table 2, it could be said that as density increases, cross section on materials decreases and also it can observe from fig2 that 55% B + 45% Galena with density of 4.70 have high cross section value and have high neutron shielding properties in compare to other samples.

Conclusions

In present study, we have examined rapid neutron shielding properties of Galena (PbS), Boron, different percentage of Galena with Boron samples by using experiment and simulation process in. The results of this study have offered new comment about the cross section of fast neutron via materials including different percentage of Boron. In our samples neutron cross section and neutron capture are mostly dependent on the Boron. For the high cross section is %45 Galena +
%55 Boron, it considered to have better shielding characteristics than any other samples. These materials could be applied for building walls of nuclear energy centrals, as moderator for nuclear reactors, in nuclear medicine departments and nuclear investigation centers, etc., and their task is to protect damages from neutron particle.

Table 2: Cross section, neutron capture and density of concretes according B percentage and Galena

Material	Cross Section	Neutron Capture	Density (g/cm3)
95%B + 5% PBS	0.2360629	2	2.606
90%B + 10% PBS	0.25027711	2	2.886
85%B + 15%PBS	0.26231717	2	3.129
80%B + 20% PBS	0.27270676	2	3.392
75%B + 25%PBS	0.28071176	4	3.655
70%B + 30%PBS	0.28776874	6	3.918

65%B + 35%PBS	0.29179318	6	4.181
60%B + 40%PBS	0.29526273	5	4.444
55%B + 45%PBS	0.2964228	2	4.707
50%B + 50%PBS	0.29597369	5	4.97
45%B + 55%PBS	0.29298008	8	5.233
40%B + 60%PBS	0.28943027	8	5.496
35%B + 65%PBS	0.28328774	11	5.759
30%B +70%PBS	0.27543998	11	6.022
25%B + 75%PBS	0.2657523	10	6.285
20%B + 80%PBS	0.25446782	12	6.548
15%B + 85%PBS	0.24107333	13	6.811
10%B +90%PBS	0.22508544	15	7.074
5%B + 95%PBS	0.2087871	15	7.337

Table 3: Concentration of Galena and Boron (B) in concretes

Material Concrete	Boron	Galena
1	%95	%5
2	%90	%10
3	%85	%15
4	%80	%20
5	%75	%25
6	%70	%30
7	%65	%35
8	%60	%40
9	%55	%45
10	%50	%50
11	%45	%55
12	%40	%60
13	%35	%65
14	%30	%70
15	%25	%75
16	%20	%80
17	%15	%85
18	%10	%90
19	%5	%95

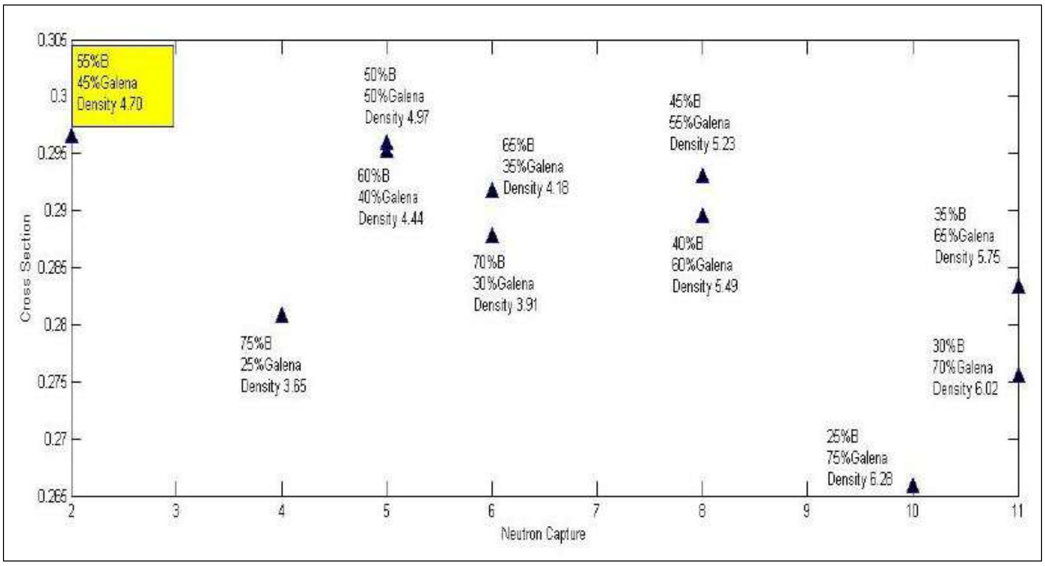

Fig 1: The measured values of Neutron Capture according Cross Section

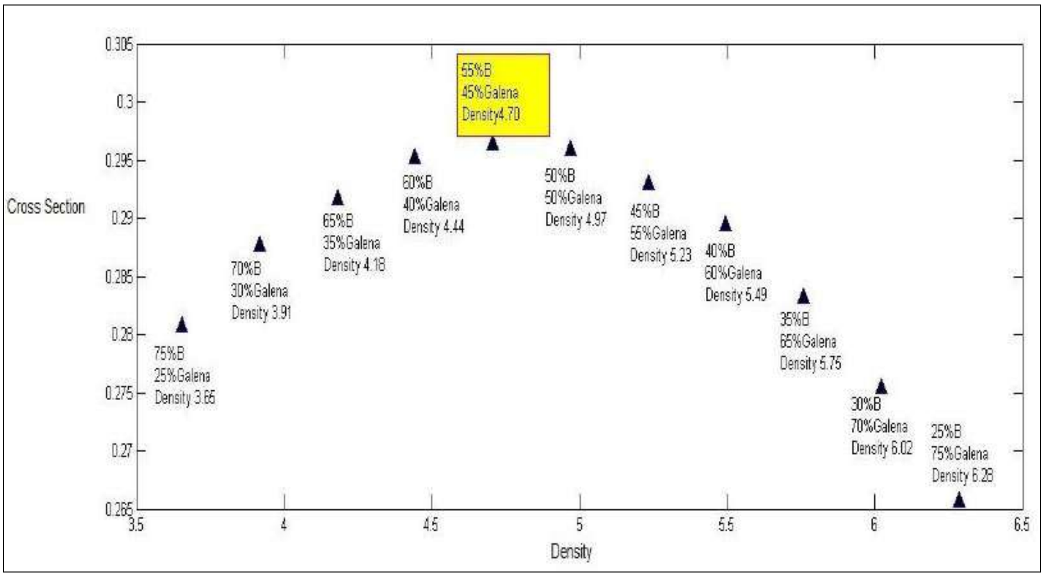

Fig 2: The measured values of Neutron Capture according Cross Section

Reference

1. Yusof Abdullah, Mohd Reusmaazran Yusof, Azali Muhamad, Zaifol Samsu, Nurhaslinda Ee Abdullah. Cement- Boron Carbid concretes as Radiation shielding material. Journal of Nuclear and Related Tejnologies, 2010, 7(2).
2. Pavlenko VI, Yastrebinskii RN, Voronov DV. Investigation of heavy radiation-shielding concrete after activation by fast neutrons and gamma radiation. Journal of Engineering Physics and Thermophysics, 81: 1062-0125. Related Technologies, 2008, 7(2).
3. Mortazavi SMJ, Mosleh-Shirazi MA, Baradaran-Ghahfarokhi M, Siavashpour Z, Farshadi A, Ghafoori, AM, *et al*. Production of a Datolite- based heavy concrete for shielding nuclear reactors and megavoltage radiotherapy rooms. Iran. J. Radiat. Res. 2010;8(1):11-15.
4. Prabhu SS. E-Bayesian estimation of the shape parameter of Lomax model under symmetric and asymmetric loss functions. International Journal of Statistics and Applied Mathematics. 2020;5(6):142-146.
5. Baştürk M, Arztmann J, Jerlich W, Kardjilov N, Lehmann E, Zawisky M. Analysis of neutron attenuation in boron-alloyed stainless steel with neutron radiography and JEN-3 gauge. J Nucl Mater. 2005;341:189-200.
6. Tschirf E. Concret as a shielding material against X-rays, gamma and neutron. Zement-und-Beton. 1976;21(5):240-244.
7. bashter II, Makarious As, Abdo AE. Investigation of hematite-serpentine and ilmenite-limonite concretes for reactor radiation shielding. Ann Nucl Energy. 1996;23(1):65-71.
8. Abdo AE. Calculation of the cross sections for fast neutrons and gamma rays in concrete shields. Ann Nucl Energy 2002;29:1977-1988.
9. Içelli O, Erzeneoğlu R. Measurement of X-ray transmission factors of some boron compounds. Radiat Meas. 2003;37:613-616.
10. Maiti M, Nandy M, Roy SN, Sarkar PK. Flux and dose transmission through concrete of neutrons from proton induced reactions on various target elements. Nucl Instrum Methods Phys Res Sect B. 2004;226(4):585-594.
11. Sun H, Jain R, Nguyen K, Zuckerman J. Sialitetechnology-sustainable alternative to Portland cement. Clean Technologies and Environmental Policy. 2009. DOI 10.1007/s10098-009-0258-8.
12. IAEA. Treatment Machines for External Beam Radiotherapy. Chapter 5, in IAEA Radiation Oncology Physics: A Handbook for Teachers and Students. International Atomic Energy Agency, Vienna. 2005.
13. Missouri Department of Natural Resources. Galena. Geological Survey and Resource Assessment Division fact sheet number 22, USA. 2002.
14. Korkut T, Karabulut A, Budak G, Korkut H. Investigation of fast neutron shielding characteristics depending on boron percentage of MgB2, NaBH4 and KBH4. J Radioanal Nucl Chem. 2010;286:61-65.